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Inhibition of corrosion of mild steel in simulated oil well water by an aqueous extract of *Andrographis paniculata*

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An aqueous extract of *Andrographis paniculata* has been used as corrosion inhibitor, in controlling corrosion of mild steel in simulated oil well water (SOWW). Weight loss method reveals that 10 mL of the extract offers 94% inhibition efficiency to mild steel immersed in simulated oil well water (SOWW). The mechanistic aspects of corrosion inhibition have been investigated by electrochemical studies such as polarization study and AC impedance spectra. Polarisation study reveals that the inhibitor system controls the cathodic reaction predominantly as revealed by the shift of the corrosion potential to the cathodic side in presence of the inhibitor system. The corrosion protective nature of the inhibitor is confirmed by the increase in the linear polarization resistance value and decrease in the corrosion current value. The formation of a protective film on the metal surface is confirmed by the AC impedance spectra. This is confirmed by the fact that there is increase in charge transfer resistance value and decrease in double layer capacitance value. The adsorption of the inhibitor molecule obeys Langmuir adsorption isotherm. The protective film has been analyzed FTIR spectra. It confirms that the inhibitor has coordinated with ferrous ion the metal surface through the polar atoms of the inhibitor molecule. The surface morphology of the protective film has been investigated by SEM and AFM. It is observed that in presence of inhibitor the surface of the corroded metal becomes smoother. The Vickers hardness of the metal surface before experimentation and after experimentation has been measured. It is observed that the surface becomes harder in presence of inhibitor than in the absence of inhibitor under the influence of corrosive medium, namely simulated oil well water. The findings have potential application in petroleum industry. The inhibitor extract can be added along with the simulated oil well water in the pipelines made of mild steel.

Keywords: AFM, *Andrographis paniculata*, Corrosion inhibition, Green inhibitor, Simulated oil well water, Surface morphology, Vicker hardness

Petroleum industry is very important industry because many transporting vehicles depend on petroleum. Many pipelines are used to transport oil well water to refineries. These pipelines are made of materials such as mild steel, various stainless steels such as L80 alloy etc., When oil well water is transported through these pipelines, they may undergo corrosion. To prevent corrosion usually inhibitors are added. Many research papers have been published on the use of corrosion inhibitors to control corrosion of pipe lines carrying oil well water.

Ansari *et al*. have used Bis (2-aminoethyl) amine-modified graphene oxide nano emulsion for carbon steel protection in 15% HCl, Effect of temperature and synergism with iodide ions. It is observed that the chemically modified GO is a promising corrosion inhibitor in the acidizing environment[1]. "Acid Gases" refer to two of the undesirable by-products of oil and gas, namely CO_2 and H_2S. The reaction of H_2S and other sulphur compounds with water increases the degree of "sour corrosion" by forming sulphuric acid. CO_2 corrosion of carbon and alloy steels is designated as "Sweet Corrosion" which is defined as the deterioration of metal components resulting from contact with gas or solutions including both CO_2 and water. CO_2 corrosion is an important problem in the oil and gas industry due to metal loss and its severe effects in terms of localized corrosion. Sotoodeh has proposed [2] a practical model to calculate and select the corrosion allowance for piping and valves in oil and gas industry. Different process parameters such as scaling, fugacity, *p*H, glycol and corrosion inhibitor injection, water cut, operating pressure and temperature as well as CO_2 partial pressure have been applied in the model.

Mpelwa *et al.*[3] have studied on the properties of the newly extended Gemini surfactants (EGS) and their application potentials in the petroleum industry. The performances of EGSs with respect to variant spacer lengths were studied through surface tension, conductivity, dynamic light scattering interfacial tension, rheological behavior, field emission electron microscopy, core flooding, and corrosion inhibition measurements. During petroleum exploration, the use of corrosion inhibitors is necessary to reduce equipment maintenance costs, to guarantee the operation safety, and to make process operation more robust. For this reason, de S. Miranda *et al.* [4] have investigated the production of polymer particles loaded with a commercial corrosion inhibitor intended for controlled release applications in oil wells. The results reveal that the morphologies of the produced particles are significantly affected by the analyzed process operation variables, such as reaction time, temperature, and feed ratios. In oil, natural gas processing and transmission, gas hydrate blockage and corrosion are two major flow assurance problems associated with transportation through steel pipelines which lead to severe safety and economic losses. To overcome these flow assurance problems in subsea flow line, industry is injecting different types of gas hydrate as well as corrosion inhibitors. However, Qasim et al. have reported that [5] the injection of these chemicals has a counter or side effect on inhibition performance in the pipeline. Water injection, air injection, air foam injection, and in-situ combustion technology are used step by step in the later period of oilfield. Oxygen corrosion caused by different development methods has become a problem that could not be ignored. The mechanism of oxygen corrosion, the influencing factors of oxygen corrosion and the new progress of oxygen corrosion countermeasures in recent years have been systematically analyzed by Yan *et al.*[6]. Anticorrosion methods for different development modes are put forward. Chemical changes to hydraulic fracturing fluids (HFFs) within fractured unconventional reservoirs may affect hydrocarbon recovery and, in turn, the environmental impact of unconventional oil and gas development. Ethoxylated alcohol surfactants, which include alkyl ethoxylates (AEOs) and polyethylene glycols (PEGs), are often present in HFF as solvents, non-emulsifiers, and corrosion inhibitors. McAdams *et al*. have reported a detailed analysis of polyethoxylates in HFF at the time of injection into three hydraulically fractured Marcellus Shale wells and in the produced water returning to the surface [7]. It has been observed that an overlooked surfactant transformation pathway that may affect the efficacy of HFF to maximize oil and gas recovery from unconventional shale reservoirs. The major low molecular inhibitors showed inhibition in the hydration of clay in the laboratory for water-based drilling fluids, according to the principle of intercalation adsorption. However, inhibitors have failed and caused serious engineering accidents in drilling oil and natural gas. Dong *et al*. have investigated the transmission of several of drilling fluids to indicate whether low molecular inhibitor for drilling can effectively inhibit the wellbore hydration. The inhibition of drilling fluid with the plugging of mud cakes, was significantly weakened based on the hydration expansion of cores and cutting recoveries[8]. Water-based drilling fluids (WBDFs) are widely used for drilling oil and gas wells. Water-based drilling fluids are considered economical and environmentally friendly compared to synthetic and oil-based drilling fluids. Water is one of the major constituents of WBDFs but causes the swelling of clay minerals in wellbore formations. Clay swelling in the wellbore has detrimental impacts on drilling operations and it leads to excessive costs of drilling operations and oil well construction. During drilling operations, the interactions of drilling fluid and clay swelling can be prevented by using various inhibiting agents that reduce the interactions of water contents with the wellbore. To develop high-performance shale inhibitors that can significantly reduce clay swelling, drilling operation costs, and environmental impacts, a significant amount of research on the industrial and academic level has been done. , the effects on the process for various polymer-based inhibitors, nitrogen-based inhibitors, ionic liquids, and surfactants based shale inhibitors have been studied in detail by Ahmed *et al.*[9]. Corrosion-protective surfaces are of the utmost relevance to ensure long-term stability and reliability of metals and alloys by limiting their interactions with corrosive species, such as water and ions. However, their practical applications are often limited either by the inability to repel low surface tension liquids such as oils and alcohols or by poor mechanical durability. Ezazi *et al.*[10]

have reported a super omniphobic surface that can display very high contact angles for both high and low surface tension liquids as well as for concentrated acids and bases. Such extreme repellency allowed for approximately 20% of the corrosion rate compared to the conventional super hydrophobic corrosion protective coatings. Such super omniphobic surfaces thus offer a wide range of potential applications, including pipelines, with sustainable corrosion protection and rust inhibitors for steel in reinforced concrete.

The present work is undertaken to investigate the inhibitive property of an aqueous extract of Andrographis paniculata in controlling corrosion of mild steel in simulated oil well water (SOWW) by weight loss method. The mechanistic aspects of corrosion inhibition have been investigated by electrochemical studies such as polarization study and AC impedance spectra. The protective film has been analysed by uv-visible absorption spectroscopy, luminescence spectroscopy and FTIR spectra. The surface morphology of the protective film has been investigated by SEM and AFM. The Vicker hardness of the metal surface before experimentation and after experimentation has been measured.

Experimental Section

Simulated oil well water (SOWW)

Simulated oil well water was prepared by dissolving 3.5g sodium chloride, 0.305g of anhydraous calcium chloride and 0.186g of magnesium chloride in double distilled water and making up to in a 500mL in standard measuring flask (SMF). Just before the experiment add sodium sulphide 0.03g and 2 mL of concentrated hydrochloric acid solution and test the smell of hydrogen sulphide gas. Now simulated oil well water is ready for use[11].

Green inhibitor, Nilavembu (Andrographis paniculata)

Nilavembu, a Siddha herb, alleviates fever, protects the liver, and provides strength to the body. It is also indicated in physical debility occurring after fever. It stimulates hepatic functions, improves appetite, enhances digestion, boosts metabolism, and reduces after Nilavembu contains four major diterpenoids, namely, Andrographolide (AP1), 14-deoxy-11, 12 didehydroandrographolide (AP3), Neoandrographolide (AP4) and 14-deoxyandrographolide (AP6). The main bioactive constituent of the nilavembu plant is Andrographolide (Fig. 1). In the whole plant, it is present around 81-186 milligram per gram (mg/g). effects of several medicines on the liver[12].

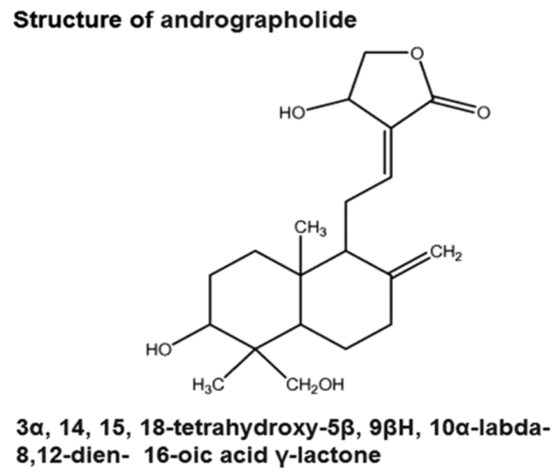

Fig. 1 — Structure of Andrographolide.

An aqueous effect of a plant leaves "Nilavembu [Andrographis paniculata (AP)]" has been prepared by boiling 50 g of shade dried leaves, filtering the suspended impurities and making up to 100 mL in a standard measuring flask. The extract was used to control the corrosion of mild steel in presence of simulated oil well water (SOWW).

Weight loss method

Weights of the three polished mild steel specimens were measured before and after immersion in various test solutions. The inhibition efficiencies were calculated from the relation

$$IE = [(CR_1 - CR_2)/CR_1]100\ \% \qquad \ldots (1)$$

where CR_1 is corrosion rate in the absence of inhibitor and CR_2 is the corrosion rate in the presence of inhibitor.

Electrochemical studies

In the present work corrosion resistance of mild steel immersed in various test solutions were measured by Polarization study and AC impedance spectra.

Polarization study

Polarization studies were carried out in a CHI Electrochemical work station model 660A. It was provided with automatic *iR* compensation facility. A three electrode cell assembly was used .

The working electrode was mild steel . A SCE was the reference electrode. Platinum was the counter electrode. From polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}), Tafel slopes anodic = b_a and cathodic = b_c and LPR (linear polarisation resistance) value. The scan rate (V/S) was 0.01. Hold time at (E_{fcs}) was zero and quiet time (s) was 2.

AC Impedance spectra

The same instrument and set-up used for polarization study was used to record AC impedance spectra also. The real part (Z') and imaginary part (Z'') of the cell impedance were measured in ohms at various frequencies. AC impedance spectra were recorded with initial E(v) = 0, high frequency (Hz = $1x10^5$), low frequency (Hz = 1),amplitude (V) = 0.005 and quiet time (s) = 2. From Nyquist plot the Values of charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated.

Surface analysis of protective film

Mild steel specimen was immersed in the inhibitor system for a period of one day. After one day the specimen was taken out, dried and subjected to various surface analysis techniques like FTIR spectra, SEM images, AFM images, Vicker hardness were recorded. FTIR spectra were recorded in Perkin-Elmer make, model spectrum two. SEM images were recorded in Cartizers make model EVO-18. Vicker hardness was recorded in Shimadzu make model HMV-27.

Results and Discussion

An aqueous effect of a plant leaves "Nilavembu [Andrographis paniculata (AP)]" has been used to control the corrosion of mild steel in presence of simulated oil well water (SOWW). The findings will be useful in petroleum technology. These inhibitors may be added to oil well water carried by pipelines made of mild steel.

The inhibition efficiency of the inhibitor system was evaluated by weight loss method. The mechanistic aspects were studied by polarisation study and AC impedance spectra.

Analysis of results of the weight loss method

Inhibition of corrosion of mild steel in SOWW

The weight loss method has been used to evaluate the inhibition efficiency of plant extract in controlling corrosion of mild steel in simulated oil well water (SOWW). The inhibition efficiencies (IE), corrosion rates of plant extract in controlling corrosion of mild steel are given in Table 1. The surface coverage of plant extract in controlling corrosion of mild steel immersed in SOWW are also given in Table 1.

Adsorption Isotherm

Inhibition of corrosion of metals and alloys are mainly due to adsorption of inhibitor molecules on the metal surface. In the case of natural product extracts, the active principles of the extracts get adsorbed on the metal surface.

The surface coverage of the inhibitor on the metal surface was calculated from the relation, surface coverage θ =IE% /100 (Table 1). A plot of C is C/ θ was made (Fig. 2). A straight line was obtained. The R^2 value was very high (0.995). All these observations indicate that adsorption of inhibitor molecules on the metal surface obey Langmuir Adsorption Isotherm.

Analysis of Polarisation curves

Corrosion parameters derived from polarisation study, namely corrosion potential (E_{corr}, Tafel slope (b_c, b_a), Linear polarisation resistance (LPR) values and corrosion current (I_{corr}) values are given in Table 2. The polarisation curves of mild steel (MS)

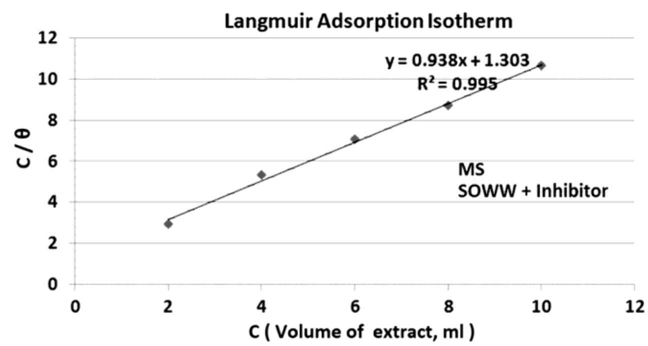

Fig. 2 — Adsorption isotherm on mild steel immersed in SOWW in presence of inhibitor.

Table 1 — Corrosion rates and Inhibition efficiency (IE) of inhibitor system [Plant extract (*AP*)] in controlling corrosion of mild steel in SOWW

Volume of plant extract, mL	Corrosion rate, mdd	Inhibition efficiency, %	θ, Surface coverage
z	14.55	-	-
2	4.656	68	0.68
4	3.6375	75	0.75
6	2.183	85	0.85
8	1.164	92	0.92
10	0.873	94	0.94

Table 2 — Corrosion parameters of mild steel immersed in SOWW in the absence and presence of an aqueous extract of a plant extract [Nilavembu (*Andrographis paniculata*)] obtained by Polarization study

System	E_{corr} V Vs SCE	b_c V/decade	b_a V/decade	LPR Ohmcm^2	I_{corr} A/ cm^2
SOWW	-0.553	3.416	8.620	1694	$2.133x10^{-5}$
SOWW + 20 mL of plant extract	-0.758	5.016	6.174	10092	$0.3850x10^{-5}$

immersed in SOWW in the absence and presence of inhibitor system are shown in Fig. 3.

It is observed from the Table 2 that when mild steel is immersed in SOWW, the corrosion potential is -0.553 mV Vs SCE: the LPR value is 1694 ohm cm^2. The corrosion current value is 2.133 x 10^{-5} A/cm^2. It is inferred from the table, that in presence of inhibitor, the corrosion potential is shifted from -0.553 to -0.758 V vs SCE. This is an cathodic shift. It suggests that the cathodic reaction is controlled predominantly. The LPR value increases (Fig. 4) from 1694 $ohmcm^2$ to10092 $ohmcm^2$. Correspondingly the corrosion current value decreases from 2.133 x 10^{-5} A/cm^2 to $0.3850x10^{-5}$ A/cm^2. These observations confirm that a protective film is formed on the metal surface. This controls the corrosion of metal [13,14]. The inhibition efficiency calculated from polarization study comes to 83.21%. The slight difference in inhibition efficiencies between the weight loss method and polarization method may be attributed to the fact, that weight loss method is an average method after immersion period of one day, polarisarion method is an instantaneous method.

Analysis of AC impedance spectra

The protective film formed on the metal surface is confirmed by AC impedance spectra. If a protective film is formed on the metal surface, the charge transfer resistance (R_t) value increases; double layer capacitance value (C_{dl}) decreases and the impedance [log (Z/ ohm)] value increases [15,16].

The AC impedance spectra of mild steel immersed in SOWW in the absence and presence of inhibitor (plant extract) are shown in Fig. 5 (Nyquist plot), Figs. 6 and 7 (Bode plots). The corrosion parameters, namely R_t, C_{dl} and impedance values are given in Table 3.

It is observed from the Table 3 that, when mild steel is immersed in SOWW, the R_t value is 268.88 $ohmcm^2$. The C_{dl} value is $1.897x10^{-8}$ F/cm^2. The impedance value is 2.547. In the presence of inhibitor, the R_t value increases (Fig. 8) from 268.88 $ohmcm^2$ to 299.29 $ohmcm^2$. The C_{dl} value decreases from $1.897x10^{-8}$ F/cm^2 to 1.7040 $x10^{-8}$ F/cm^2. The impedance value increases from 2.547 to 2.591.

Implication

Mild steel samples were immersed in SOWW with plant extract [Nilavembu (Andrographis Paniculata] to evaluate corrosion inhibition efficiency .of the plant extract. The inhibition efficiency increases with the increase in concentration of plant extract. Inhibition efficiency up to 94% for mild steel were achieved. The results indicated that the corrosion rate decreases, as the concentration of plant extract inhibitor increases and simultaneously it enhances the inhibition efficiency of the samples. This finding may find application in petroleum industry. To prevent corrosion of mild steel pipelines carrying oil well water, the plant extract under investigation may be added, along with oil well water.

Analysis of SEM

SEM analysis has been widely used in corrosion inhibition study. SEM images are recorded for

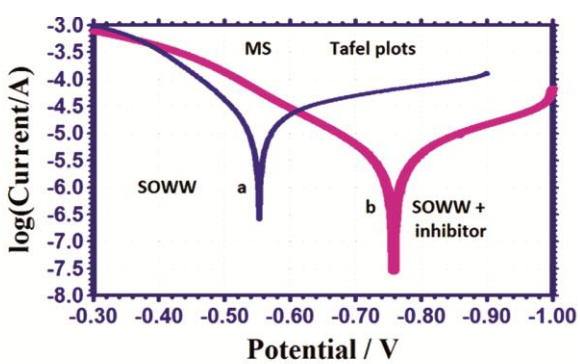

Fig. 3 — Polarisation curves of mild steel immersed in various test solutions.(a) SOWW, (b) SOWW + inhibitor.

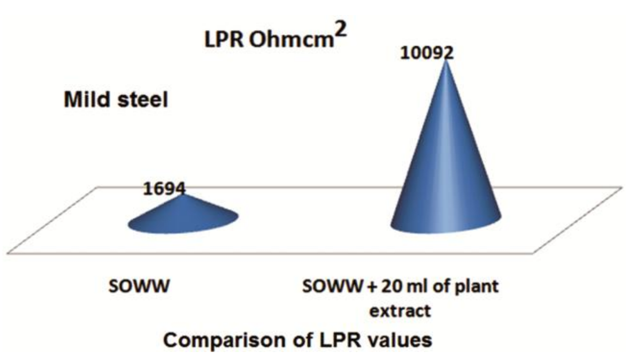

Fig. 4 — Comparison of LPR values

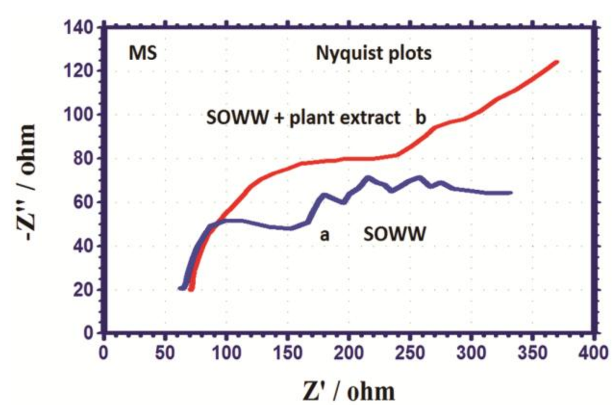

Fig. 5 — AC impedance spectra of mild steel immersed in various test solution (Nyquist Plot); (a) SOWW; (b) SOWW + Plant extract.

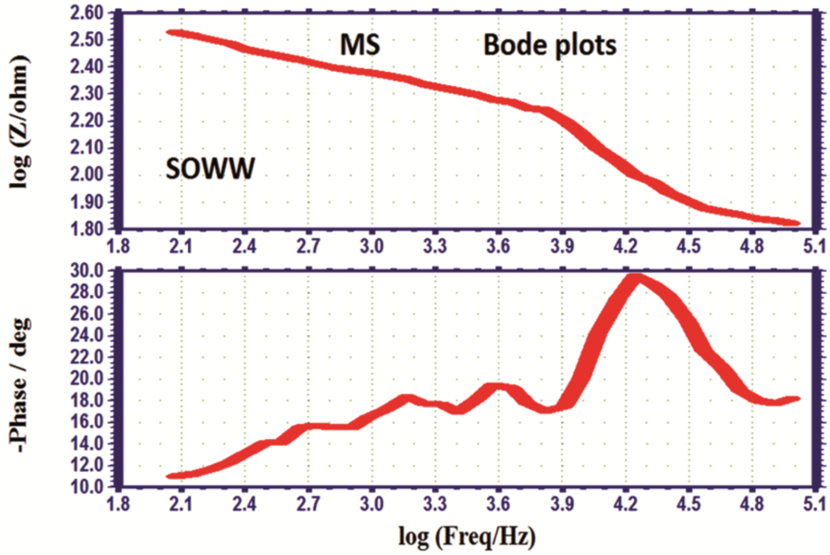

Fig. 6 — AC impedance spectra of mild steel immersed in SOWW (Bode Plots).

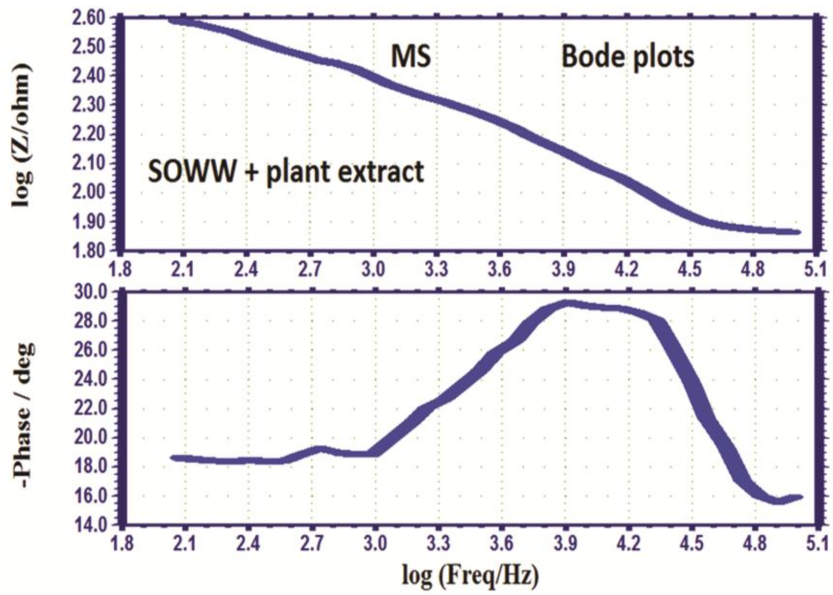

Fig. 7 — AC impedance spectra of mild steel immersed in SOWW + Plant extract (Bodeplots).

Table 3 — Corrosion parameters of mild steel (MS) immersed in simulated oil well water (SOWW) in the absence and presence of an aqueous extract of a plant extract [Nilavembu (*Andrographis paniculata*)] obtained by AC impedance spectra

System	R_t Ohmcm^2	C_{dl} F/ cm^2	Impedance Log(z/ohm)
SOWW	268.88	1.897x10^{-8}	2.547
SOWW + 20 mL of plant extract	299.29	1.7040 x10^{-8}	2.591

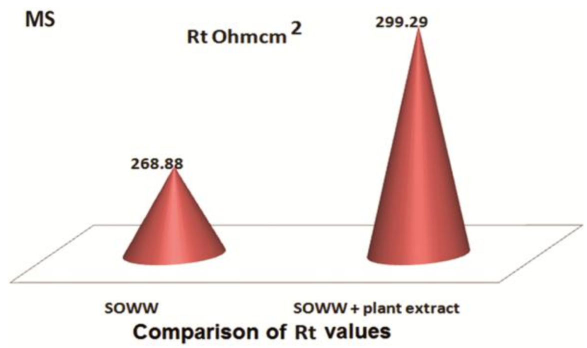

Fig. 8 — Comparison of Rt values

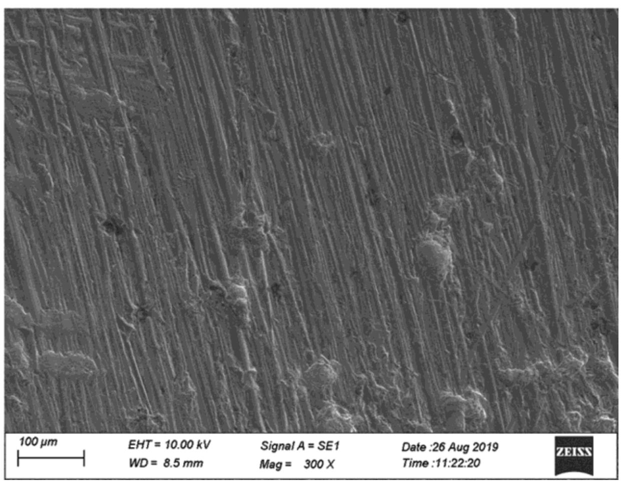

Fig. 9 — SEM image of polished mild steel.

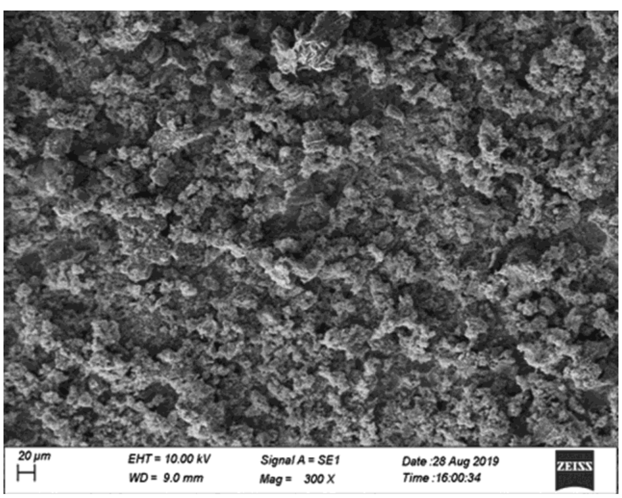

Fig. 10 — SEM image of mild steel immersed in SOWW

polished metal surface, metal surface immersed in corrosive medium and metal surface immersed in corrosive medium containing the inhibitor system.

In the present study SEM images were recorded for polished mild steel surface (system A), polished mild steel surface immersed in corrosive medium (SOWW) (system B) and polished mild steel surface immersed in corrosive medium (SOWW) containing the inhibitor system(system C) [17-19]. The images are shown in Figs. 9-11.

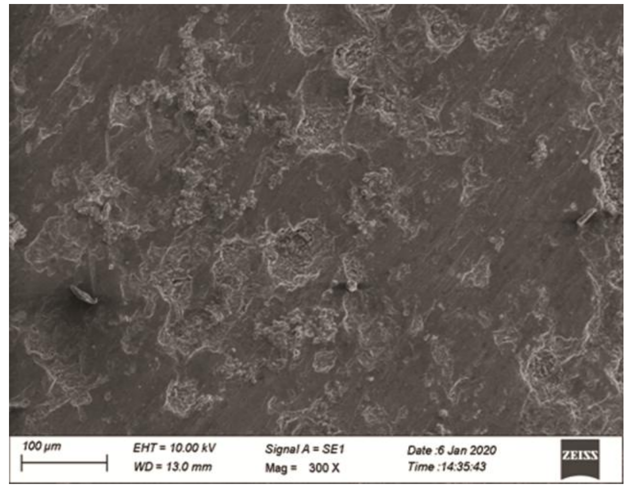

Fig. 11 — SEM image of mild steel immersed in SOWW + Inhibitor system.

Table 4 — Vicker Hardness (HV) of various surfaces measured along L1 and L2

System (load) S.No	L1	L2	HV
Polished metal (25g) 1	20.38	21.31	107
Polished metal (25 g) 2	19.89	21.94	106
Polished metal (50g) 1	23.31	24.62	161
Polished metal (50 g) 2	23.43	24.49	162
Corroded metal (25g) 1	20.65	23.33	95.8
Corroded metal (25 g) 2	20.76	23.27	95.6
Corroded metal (50g) 1	26.82	29.62	116
Corroded metal (50 g) 2	27.53	30.03	112
Inhibited metal (25g) 1	19.54	20.77	114
Inhibited metal (25 g) 2	19.48	20.97	113
Inhibited metal (50g) 1	24.31	26.48	144
Inhibited metal (50 g) 2	24.19	25.61	150

It is observed that for system A the surface is very smooth. For system B the surface is very rough. Pits are noticed due to corrosion. For system C the surface is smooth, due to the formation of protective film. Thus the SEM is used in corrosion inhibition study.

Analysis of Vicker hardness

The Vicker hardness was measured for polished mild steel surface (system A), polished mild steel surface immersed in corrosive medium (SOWW) (system B) and polished mild steel surface immersed in corrosive medium (SOWW) containing the inhibitor system (system C). The values are give in Table 4. The Vicker hardness was measured for 25 g load and 50 g load at two places each.

Table 5 — AFM parameters of mild steel mild steel immersed in corrosive medium (SOWW) in the presence and absence of inhibitor , an aqueous extract of a plant extract [Nilavembu (*Andrographis Paniculata*)

S. No	Specimen	RMS (Rq) Roughness (nm)	Average (R_a) Roughness (nm)	Maximum peak-to- valley height (Ry) (nm)
1	Polished mild steel	148.72nm	135.48nm	468.21nm
2	Polished mild steel immersed in corrosive medium (SOWW) (Blank)	563.38nm	473.36nm	2081.8nm
3	polished mild steel immersed in corrosive medium (SOWW) containing the inhibitor system	127.88nm	101.93nm	553.42nm

It is observed that for system A the hardness is high. For system B the hardness is low because the corroded surface contains iron oxide film which is porous and amorphous surface is very rough. Pits are noticed due to corrosion. For system C the surface is smooth, due to the formation of protective film. The hardness is in between that of system A and B. That is, lower than that of polished metal but higher than that of corroded surface. Thus the Vicker hardness is used in corrosion inhibition study.

AFM study

The AFM images were recorded for polished mild steel surface (system A), polished mild steel surface immersed in corrosive medium (SOWW) (system B) and polished mild steel surface immersed in corrosive medium (SOWW) containing the inhibitor system (system C). The AFM parameters are given in Table 5.

The roughness values of various system are given in Table 6. It is observed that the average roughness value (Ra, 75.453) of inhibitor medium system is higher that of the polished metal (Ra, 65.932) but lower than that of the corrosive system (Ra, 268.98). This nano film protects the metal from corrosion. Similar is the case with RMS roughness(Rq) and maximum peak-to-valley height (Ry)[20].

Analysis of FTIR spectra

FTIR spectra have been used to confirm the formation of protective film on the metal surface, during corrosion inhibition process[14] . In the present study, an aqueous extract of nilavembu has been used as corrosion inhibitor. The main active principle of this extract is andrographolide, 3α, 14, 15, 18-tetrahydroxy-5β, 9βH, 10α-labda-8, 12-dien-16-oic acid γ-lactone, (Fig. 1). A few drops of the extract was placed on glass plate and dried. A solid mass was obtained. It was mixed with KBr and made in the pellet form and FTIR spectrum was recorded. The FTIR spectrum of the protective film formed on the metal surface after immersion for a period of one day, in the solution containing simulated oil well water and extract solution.

Table 6 — Frequencies of various functional groups

Functional group	Extract cm^{-1}	Film cm^{-1}
OH	3423	3372
Aliphatic CH-	2923, 2852	2927,2850
C=O	1638	1626
C=C	1638	1626
C-O aliphatic ether	1115, 1038,	1115,1070, 1020

It is observed, that the stretching frequencies of various functional groups have shifted. The results are summarized in Table 6. The shifts in frequencies of various functional groups indicate that the inhibitor has coordinated with Fe^{2+} on the metal surface, through oxygen atoms of hydroxyl group, carbonyl group and alkyl ether, and also through pielectrons of the alkene group. Thus the study leads to the conclusion that the protective film consists of iron andrographolide complex formed on the metal surface[21,22].

Conclusion

As an environmentally friendly inhibitor, an aqueous extract of Andrographis paniculata has been used as corrosion inhibitor, in controlling corrosion of mild steel in simulated oil well water (SOWW). Weight loss method has been used to evaluate the corrosieon inhibition efficiency. It is observed that 10 ml of the extract offers 94% inhibition efficiency to mild steel immersed in simulated oil well water (SOWW). The mechanistic aspects of corrosion inhibition have been investigated by electrochemical studies such as polarization study and AC impedance spectra. Polarisation study reveals that the inhibitor system controls the cathodic reaction predominantly as revealed by the shift of the corrosion potential to the cathodic side in presence of the inhibitor system. The corrosion protection nature of the inhibitor is confirmed by the tremendous increase in the linear polarization resistance value and decrease in the corrosion current value. The formation of a protective film on the metal surface is confirmed by the AC impedance spectra. This is confirmed by the fact that there is increase in charge transfer resistance value and decrease in double layer capacitance value. The adsorption of the inhibitor molecule obeys Langmuir adsorption isotherm. The R^2 value is very high (0.995). The protective film has been analyzed FTIR spectra. It confirms that the inhibitor has coordinated with ferrous ion the metal surface through the polar atoms of the inhibitor molecule, The surface morphology of the protective film has been investigated by SEM and AFM. It is observed that in presence of inhibitor the surface of the corroded metal becomes smoother. The Vickers hardness of the metal surface before experimentation and after experimentation has been measured. It observed that the surface becomes harder in presence of inhibitor than in the absence of inhibitor under the influence of corrosive medium, namely simulated oil well water. The findings have potential application in petroleum industry. The inhibitor extract can be added along with the simulated oil well water in the pipelines made of mild steel.

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